Evaluation of Cross Laminated Timber Resistance to Termite Attack

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ABSTRACT

Cross laminated timber (CLT) is a relatively recent addition to the North American timber construction market. CLT has been successfully used for construction in Europe and, in the past few years, manufacturers have looked forward to expanding the use of this product into the North American market. However, no termite susceptibility experiments have been published for the product and no standards exist for testing of the CLT and other mass timber products against termites. It is extremely important to evaluate the resistance to degradation of CLT, especially if the manufacturers are trying to implement this product in areas where the occurrence of termite infestation is high. The objective of this paper is to describe an ongoing project on evaluation of CLT resistance against subterranean termites in the southeastern United States. To date, results indicate that the material is susceptible to subterranean termite attack. In terms of testing and standard development, results suggested that it may be difficult to evaluate damage using conventional methods such as mass loss and visual rating, and more advanced imaging systems may give a more thorough evaluation of the material.

Keywords: subterranean termites, mass timber products, mass loss, visual rating

INTRODUCTION

Cross-laminated timber (CLT) is a part of a new generation of mass timber products that was developed in Europe and has since gained space in residential and non-residential construction in many countries. In the 1990s, Austria undertook a joint effort between industry and academia that resulted in the development of CLT (FPInnovations, 2010).

CLT consists of crosswise glued layers of timber boards alternating grain direction between layers. Panels are produced with 3, 5, or 7 layers (Van de Kuilen et al., 2011). Insulations and facades are easily attached to the timber panels during construction. Other advantages are the high thermal and sound insulation that CLT panels provide (Frangi et al., 2009).

CLT is considered a recent addition to the North American timber construction market. In parts of Canada and the northwestern U.S., CLT has been used in the mid-rise and tall construction market. CLT has been used in various applications in European and a limited number of North American markets, competing primarily with the pre-cast lightweight concrete panel market. There are currently over one hundred CLT-based buildings in Europe (Mohammad et al., 2012).

To expand the range of use for this product throughout the U.S., an examination of CLT resistance to degradation that commonly occurs in the areas served by the U.S. timber construction materials market must be undertaken. The objective of this study is to develop test protocols for examining susceptibility of CLT to termites and to provide information on CLT termite resistance levels.

MATERIAL AND METHODS

In development of the laboratory scale assay, AWPA Standard E1-17 (AWPA, 2017a) was selected as the basis for test design. This standard is meant for testing solid materials in a laboratory scale. This standard calls for test pieces with a dimension of 1” x 1” x ¼” (25 mm x 25 mm x 6 mm). However, a piece of this size cut from CLT would only test the wood from which it is made or the adhesive interface between two adjacent pieces within the panel. It was therefore determined that the product should be tested at its full thickness.

Materials for this test were obtained from industry contacts at SmartLam, LLC (CLT) and from Component Builders, Inc. (parallel strand lumber [PSL] and laminated veneer lumber [LVL]). Specimens for termite testing (n = 25) were cut into 10.16 x 10.16 x 2.54 cm test blocks and included four treatments – CLT, untreated PSL, treated PSL, and LVL (Figure 1). PSL samples were treated to UC4A (AWPA 2017b), retention 2.4 kg/m^3, with copper azole type C (CA-C) (AWPA 2017c). In addition, five test blocks of CLT were prepared including sand, sterile distilled water with no termites used as negative control.

Figure 1. Conditioning test blocks to 12% EMC in an environmental chamber.

All samples were autoclaved and conditioned in an environmental chamber (70°F, 64% RH) to an EMC of 12% (equilibrium moisture content) with conditions adjusted to prevent mold growth and promote termite survival. Native subterranean termites (*Reticulitermes sp.*) were collected from one log found in the Sam D. Hamilton National Wildlife Refuge and used within two weeks of collection.

Test containers were eight-liter food-grade clear plastic containers. For the test, sterilized containers with sand substrate (1715 g sand per container) were labeled according to treatment and moistened with 180 mL of sterile distilled water. Once conditioned to a stable weight, a weighed test block was added to each of the 25 containers. Cleaned termites were counted to a total of 1000 three times and an average weight was taken. Approximately 1000 termites (3g of termites per container) with less than 10% soldiers were added to each of the 20 containers requiring termite exposure. Treatment containers were sealed (with a lid that had a hole plugged with sterile cotton for air exchange), weighed, and held at 70°F, 64% RH, 12% EMC for the duration of the test (Figure 2).

Figure 2. Test containers for *Reticulitermes sp.* lab scale test (left) and mud tube construction on the vertical face of CLT test block (right).

Containers were monitored daily for growth of mold or other fungi and for activity of termite populations. At four (4) weeks, test blocks were removed and live termites were counted. Blocks were photographed, termites were carefully knocked out of the blocks, and live specimens were counted. The blocks were then cleaned of mud tubes and debris and re-weighed. The samples were placed back in the environmental chamber under the same conditions as the pre-test (70°F, 64% RH, 12% EMC) to equilibrate to pre-test conditions. The samples were then weighed again to determine mass loss. Each block was also visually evaluated in accordance with AWPA E21-17 visual rating system (Table 1) (AWPA, 2017).

Table 1. Grading system according to AWPA E21-16 (AWPA, 2016).

Rating	Description
10	Sound
9.5	Trace, surface nibbles permitted
9	Slight attack, up to 3% of cross sectional area affected
8	Moderate attack, 3-10% of cross area affected
7	Moderate/severe attack and penetration, 10-30% of cross sectional area affected
6	Severe attack, 30-50% of cross sectional area affected
4	Very severe attack, 30-50% of cross sectional area affected
0	Failure

The following equations show how to calculate mass change (%), and termite mortality:

$$Mass\ change\ \% = \frac{(W_1 - W_2)}{W_1}\ x\ 100$$

Where W_1 = conditioned mass prior to testing (g), W_2 = conditioned mass following testing (g).

$$Termite\ mortality\ \% = \frac{(1000 - \#\ living\ termites\ at\ test\ end)}{1000} x\ 100$$

The statistical analyses and associated graphs were completed using SAS version 9.4 (SAS Institute 2013). Differences in wood consumption of termites among mass timber products were compared using the Tukey test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

The treated PSL and the CLT control samples increased in mass over the course of 4 weeks (-0.33%, and -0.05%, respectively). CLT samples (1.04%) were the most significantly attacked samples from all groups of mass timber products tested. LVL samples (0.32%) were significantly higher in mass loss than treated PSL (-0.33%). There was no significant difference between PSL (0.14%) and CLT control (-0.05%) samples (Table 2). The weight increase in treated PSL and CLT control is possibly the result of water uptake, which stained the surface exposed to the damp sand on each block. The boxplot for mass loss versus different mass timber products is shown in Figure 3. The increase in weight may also be a result of debris left behind during termite excavation. Some, but not all, of this debris may have been removed during disassembly.

The average termite mortality for the LVL specimens was 96.7%, which was higher than the termite mortality of PSL and CLT blocks (63.1% and 40.3%, respectively). Treated PSL specimens showed 100% termite mortality.

Figure 4 shows photographs and x-rays at the end of the test period. X-rays were taken using an Inspex® 2-D wide-format x-ray located in the Department of Sustainable Bioproducts at Mississippi State University. Comparisons between photographic images and x-rays were made to determine extent of termite infestation. While photographic images show surface damage to test blocks, as well as excavations and boring activity, the resolution of the x-rays does not appear to be high enough to determine internal excavation or tunneling activity. Superficial surface damage that is visible to the eye does not show a strong contrast when processed with the related x-ray imaging software (DispXline and ImageJ).

When graded by the visual rating scale included in AWPA E1-17, which judges attack based on approximate percentage of test block impacted by feeding behavior, CLT test blocks rated between 9 and 9.7 (slight attack to trace surface nibbles only). Treated PSL and termite-free control blocks were all rated at 10 (no visible damage). The LVL and untreated PSL samples were graded similarly against the standard, which had similar visual rating values of 9.7 and 9.6, respectively (slight attack to trace nibbles). A possible disadvantage of this type of rating for large blocks is that the rating scale only evaluates visual surface damage and does not take into account internal excavations that may be within the product. If termites operate within the material, they may be undetected for some time. Additionally, the larger surface area of test blocks may invalidate the scale at which the standard visual rating may be applied.

X-ray images of 4-week exposed blocks (AWPA E1-16) did not indicate internal damage from termite exposure. However, it is also very difficult to define the surface damage that is apparent in the photographic images with the x-ray imaging software. After repeated image filtering and adjustment in both DispXline and ImageJ software, it was determined that this type of x-ray imaging does not provide a high enough resolution to delineate shallow or small excavation damage done during the standard timeline of testing.

Table 2. Mass loss in termite-exposed and control blocks over the duration of test.

Treatment*	Pre-test conditioned weight (g)	Post-test conditioned weight (g)	Mass Loss (g)	Mass Loss (%)	Visual Rating (AWPA E1)	Termite Mortality (%)
LVL_1	315.06	313.23	1.83	0.58	9	83.7
LVL_2	312.80	311.60	1.20	0.38	9.5	100.0
LVL_3	308.49	307.45	1.04	0.34	9.7	100.0
LVL_4	319.38	317.74	1.64	0.51	9.5	100.0
LVL_5	314.22	314.91	-0.69	-0.22	9.7	100.0
Average			**1.00**	**0.32b****	**9.5**	**96.7**
PSL_1	207.78	206.34	1.44	0.69	9.5	67.4
PSL_2	204.26	202.89	1.37	0.67	9.5	62.0
PSL_3	206.01	206.42	-0.41	-0.20	10	100.0
PSL_4	204.87	206.24	-1.37	-0.67	9.5	50.4
PSL_5	208.14	207.67	0.47	0.23	9.5	35.5
Average			**0.30**	**0.14bc****	**9.6**	**63.1**
PSL-T_1	197.24	196.21	1.03	0.52	10	100.0
PSL-T_2	183.32	183.82	-0.50	-0.27	10	100.0
PSL-T_3	192.82	194.10	-1.28	-0.66	10	100.0
PSL-T_4	195.12	196.49	-1.37	-0.70	10	100.0
PSL-T_5	196.60	197.67	-1.07	-0.54	10	100.0
Average			**-0.64**	**-0.33c****	**10**	**100.0**
CLT_1	127.18	125.65	1.53	1.20	9.7	51.0
CLT_2	133.86	133.00	0.86	0.64	9	15.3
CLT_3	138.13	136.38	1.75	1.27	9.7	37.3
CLT_4	136.80	135.16	1.64	1.20	9.5	47.9
CLT_5	124.56	123.43	1.13	0.91	9.7	50.0
Average			**1.38**	**1.04a****	**9.5**	**40.3**
CLT_C_1	130.37	130.70	-0.33	-0.25	N/A	N/A
CLT_C_2	124.14	123.72	0.42	0.34	N/A	N/A
CLT_C_3	137.96	138.28	-0.32	-0.23	N/A	N/A
CLT_C_4	130.73	130.62	0.11	0.08	N/A	N/A
CLT_C_5	143.47	143.75	-0.28	-0.20	N/A	N/A
Average			**-0.08**	**-0.05bc****	**N/A**	**N/A**

*** LVL = Laminated Veneer Lumber; PSL = Parallel Strand Lumber – Untreated; PSL_T = Parallel Strand Lumber – Treated; CLT = CLT termite-exposed blocks; CLT_C = CLT controls.**

**** Significant difference in mean mass loss among mass timber products are indicated by different letter at α =0.05**

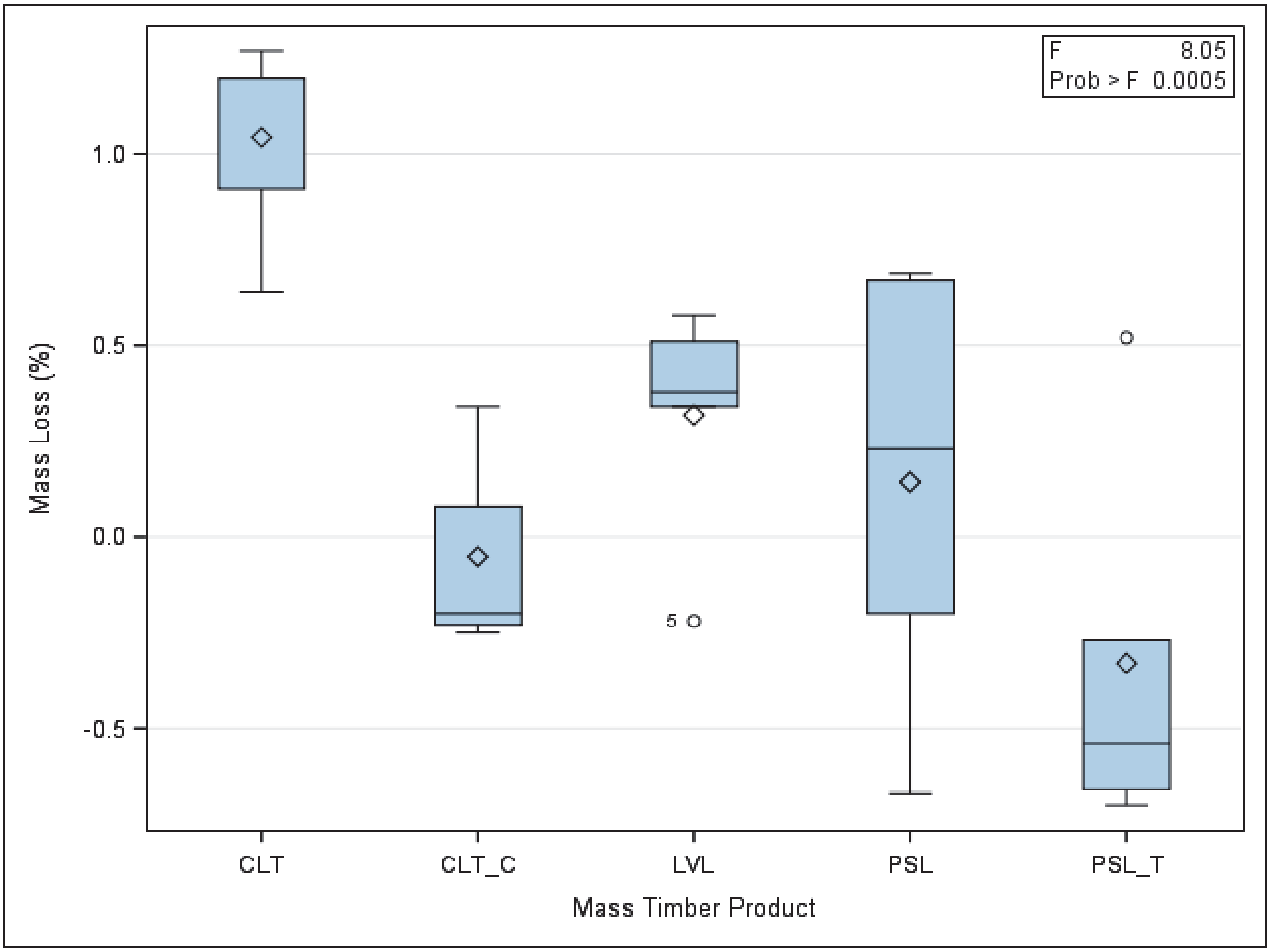
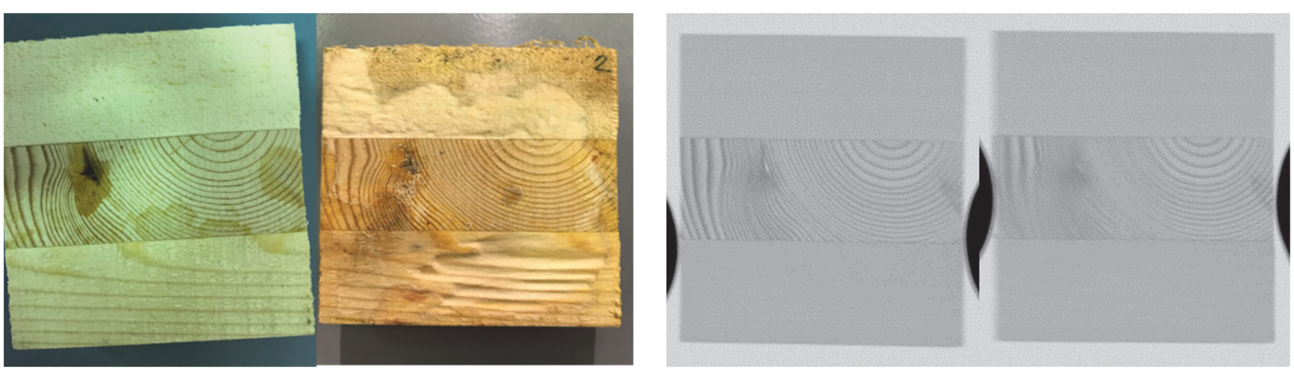


Figure 3. Boxplot distribution of mass loss by mass timber products.
*** CLT = CLT termite-exposed blocks; CLT_C = CLT controls; LVL = Laminated Veneer Lumber; PSL = Parallel Strand Lumber – Untreated; PSL_T = Parallel Strand Lumber – Treated.**



(A) (B) (C) (D)

Figure 4. Photographs and x-rays of termite-exposed block CLT-2. (A) Block CLT-2 after conditioning, prior to termite exposure. (B) Block CLT-2 after 4 weeks of exposure to termites. Evidence of feeding can be seen most heavily at the bottom right of the exposed surface. (C) X-ray of Block CLT-2 prior to testing. (D) X-ray of Block CLT-2 after testing. All images are of the exposed surface of the test block location.

CONCLUSIONS

Results from this study suggest that CLT, left unprotected, is susceptible to attack by subterranean termites. In addition, mass timber products, such as CLT, may be susceptible to water absorption. This appears to make both this type of testing and calculation of mass loss from termite feeding difficult, particularly when testing periods are shorter (i.e., 4-week lab test). This is also directly related to the size of the test block used for the laboratory study. Since larger specimens are needed to properly simulate mass timber products materials, test blocks may need to be exposed for longer periods of time to be able to identify differences in termite susceptibility. All of these factors need to be taken into consideration in the development of termite susceptibility standards. Visual rating and termite mortality appear to give a more complete picture of the within mass timber products, when paired with mass change data, but may not tell the whole story.

In terms of visual ratings, excavations from termites can be visualized easily when on the surface of the product, but may be more difficult to quantify in their extent when the majority of the tunneling is internal to the mass of wood. 2-D x-ray imaging may be a useful addition to visual inspection when tunneling activity is extensive (i.e., over a long period of time); however, shallow surface excavations during feeding remain difficult to visualize using 2-D x-ray. The authors are collaborating with imaging specialists at Mississippi State University and Nikon, Inc., to produce high resolution images of internal damage caused by termite tunneling behavior in cross-laminated timber blocks. With time, it is possible that an appropriate scanning technology will be developed to simplify the examination of CLT products in-use for termite activity.

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